POTASSIUM, SODIUM, AND CHLORIDE NUTRITION IN SALINISED PHASEOLUS TISSUES AS A BASIS OF SALT TOLERANCE

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Salt tolerance is not exclusively correlated with adaptations to Na^+ and Cl^- toxicity *per se* but also reflects adaptations to secondary effects of salinity such as water deficit and impaired nutrient acquisition (Maathius and Amtmann, 1999). The capacity of plants to counteract salinity stress will strongly depend on the status of the K^+ nutrition. In particular, the crucial role of K^+ homeostasis in salt tolerance mechanisms of salinized plants have been placed centre stage (Kamel and El-Tayeb, 2004). Imposition of salt stress results in a massive efflux of K^+ from cells (Chen et al. 2005) and significantly reduces the intracellular pools of K^+ (Cuin et al. 2003). Mitigation of this loss strongly correlates with the level of salt tolerance. The study reported here represents a contribution to the K^+, Na^+, and Cl^- relations in salinised *Phaseolus* spp.

MATERIALS AND METHODS

Two wild and two cultivated species of *Phaseolus* differing in salt tolerance were used in this study: *P. vulgaris* PI325687, a wild salt-tolerant type (WT); *P. acutifolius* G40169, a wild salt-sensitive type (WS); *P. vulgaris* G04017, a cultivated salt-sensitive type (CS); and *P. acutifolius* G40142, a cultivated salt-tolerant type (CT). Plants were grown in nutrient solution under greenhouse conditions at Universidad Michoacana, Mexico between April and July 2007. Seedlings were allowed to grow with no salinity stress until the emergence of the first trifoliate leaf, when several NaCl treatments were added to the solutions (0, 60 and 90 mM). A randomized complete block design with a split-plot arrangement of salt treatments and six replications was used. Tissue was ashed at 500 ^{0}C for 8 h, followed by dissolution in 1 mM HCl (Basta and Tabatai 1985). Sodium and potassium concentrations were determined by flame emission using an Atomic Absorption Spectrometer (Varian SpectrAA-220FS; Mulgrave, Australia). Chloride concentration was determined colorimetrically using an UV/BIS Spectrometer (Lamda 40 PE; Uberlingen, Germany). Data were analyzed using GLM procedure (SAS, 2002).

RESULTS AND DISCUSSION

Tissue concentration of Cl^- and Na^+ ions increased significantly in response to salt treatments (Table 1). However the magnitude of the Cl^- increments, were always higher than those on Na^+ at all NaCl levels. Saline-induce changes in minerals concentration varied with plant organ and ion. In all species, Na^+ concentration increased almost equally in stems and roots, whereas the concentration of Cl^- increased more in stem and leaves than in roots. Species differed in leaf Na^+ accumulation. *P. acutifolius* CT was able to exclude Na^+ from leaves at 60 mM NaCl. In contrast, all other *Phaseolus* species accumulated Na^+ in their leaves as salt levels increased. Salinity reduced K^+ concentration in the root, stems and leaves of all species. However, decrease in K^+ concentration on stems of *P. vulgaris* species was greater than leaves and roots (Table 1). *P. acutifolius* species had higher K^+ on leaves than *P. vulgaris* species at 60 and 90 mM NaCl. At moderate and high salinity levels, leaf K^+ concentration on *P. acutifolius* species were about 28 to 35% higher at day 20 than those observed on *P. vulgaris* species. Potassium plays a predominantly osmotic role in plants (Maathius and Amtmann

1999), and has high mobility throughout the entire plant through selective K^+ transport mechanisms that can operate at high rates. Moreover, lower concentrations of this nutrient in leaves may reduce their capacity for osmotic adjustment and turgor maintenance, and reduce activation of crucial enzymatic reactions, protein synthesis and homeostasis (Cuin et al. 2003). The maintenance of higher leaf K^+ concentrations in salt-tolerant *Phaseolus* species could be, by far, one of the most important mechanisms underlying superior salt tolerance as reported in *P. filiformis* (Bayuelo et al. 2003).

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Table 1. Effects of external NaCl content on mineral composition of leaves, stem and roots of *Phaseolus* species.

Species/Genotype	Leaves			Stem			Root		
NaCl (mM)	mmol kg^{-1} dry weight								
	Na^+	K^+	Cl^-	Na^+	K^+	Cl^-	Na^+	K^+	Cl^-
P. vulgaris PI325687									
0	66.7c	1381.7a	9.2c	106.7c	1307.5a	15.8c	110.0b	1302.5a	29.2c
60	130.0b	1020.8b	1077.5b	221.7b	1076.7b	658.3b	422.5a	838.3b	662.5b
90	159.2a	746.7c	2152.5a	285.0a	830.8c	1341.7a	460.0a	778.3b	999.2a
P. vulgaris G04017									
0	60.0b	1289.2a	1.7c	71.7b	2267.5a	1.7c	30.8c	1403.3a	25.0c
60	143.3a	849.2b	766.7b	275.8a	1526.7b	671.7b	320.8b	805.8b	480.8b
90	154.2a	726.7b	1895.0a	267.5a	1271.7c	1261.7a	480.0a	702.5b	879.2a
P. acutifolius G40169									
0	49.2c	1430.0a	21.7a	34.2c	1428.3a	31.7c	58.3b	1772.5a	45.0c
60	165.8b	1213.3b	933.3b	257.5b	876.7b	442.5b	376.7a	900.8b	451.7b
90	222.5a	1032.5c	1889.2c	309.2a	704.2c	880.0a	446.7a	495.0c	1040.0a
P. acutifolius G40142									
0	74.2b	1221.7a	21.7c	61.7b	1187.5a	25.8c	85.0b	2157.5a	34.2c
60	90.0b	951.7b	1109.2b	289.2a	1072.5a	417.5b	349.2a	905.0b	630.0b
90	267.5a	926.7b	2200.8a	255.8a	611.7b	842.5a	370.8a	788.3b	965.0a

Values are means of six replicates after 20 days salt exposure. Differences among treatments are given according to Duncan Multiple Range Test. *, **, *** Significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$.